E-lens Related Beam Dynamics Studies

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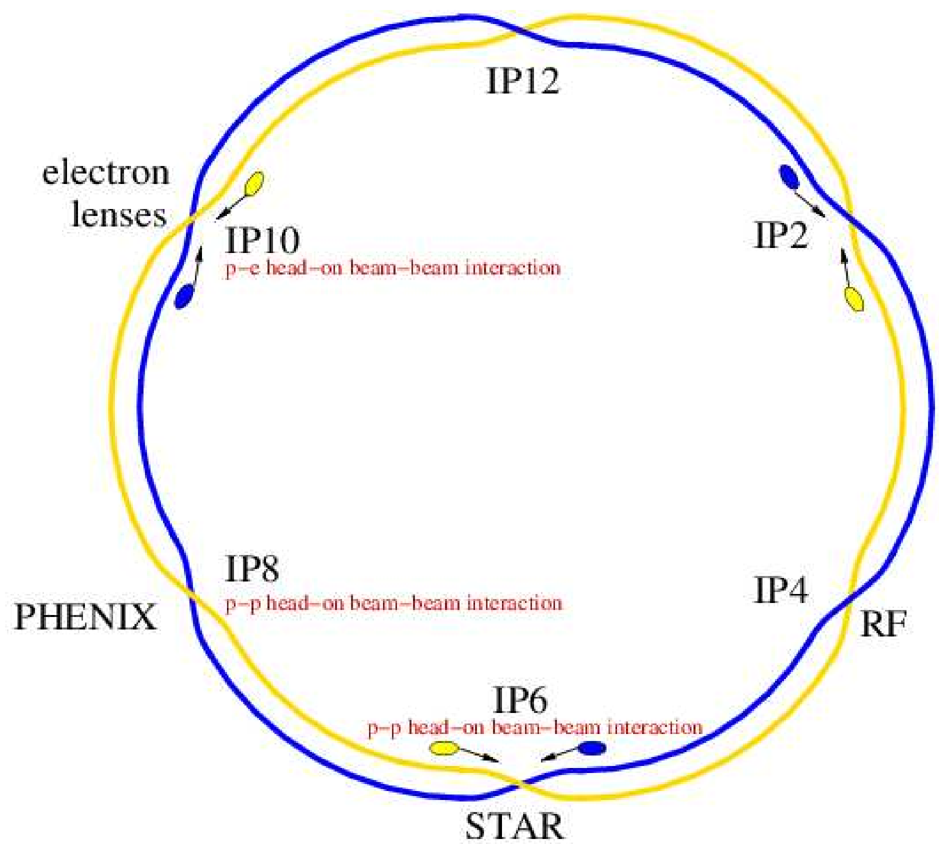
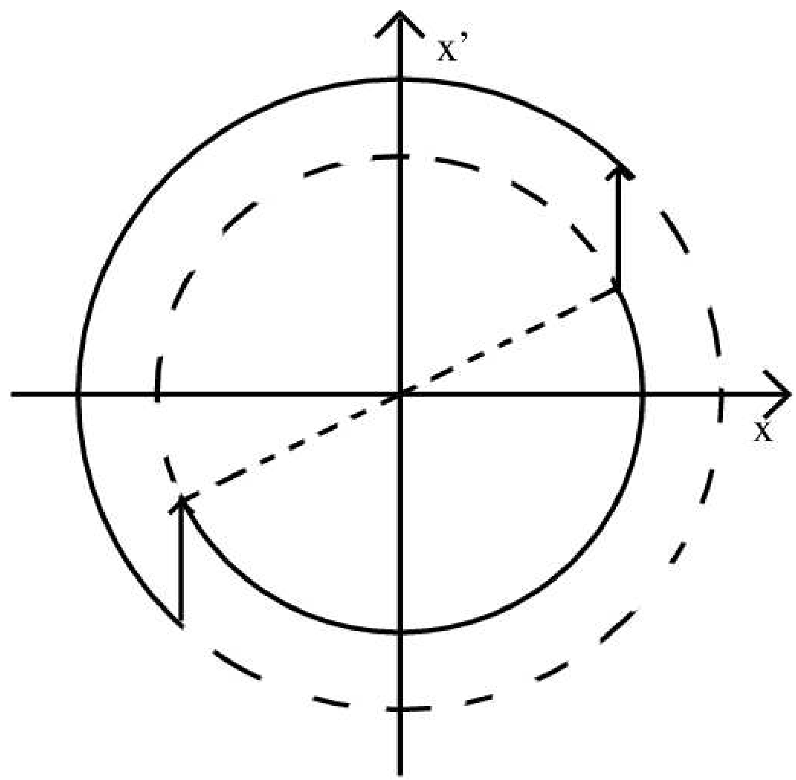
RHIC beam-beam compensation scheme



Nonlinear beam-beam kick at IP8 is compensated by opposite kick at IP10

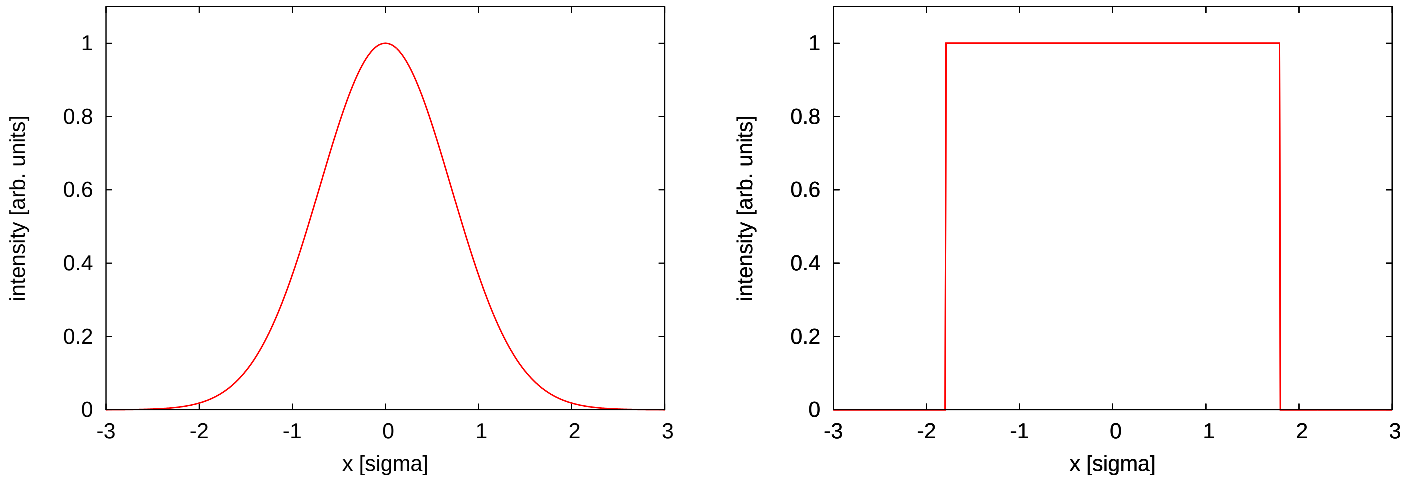
Requirements

- Betatron phase advance of $k \cdot \pi$ between IPs 8 and 10



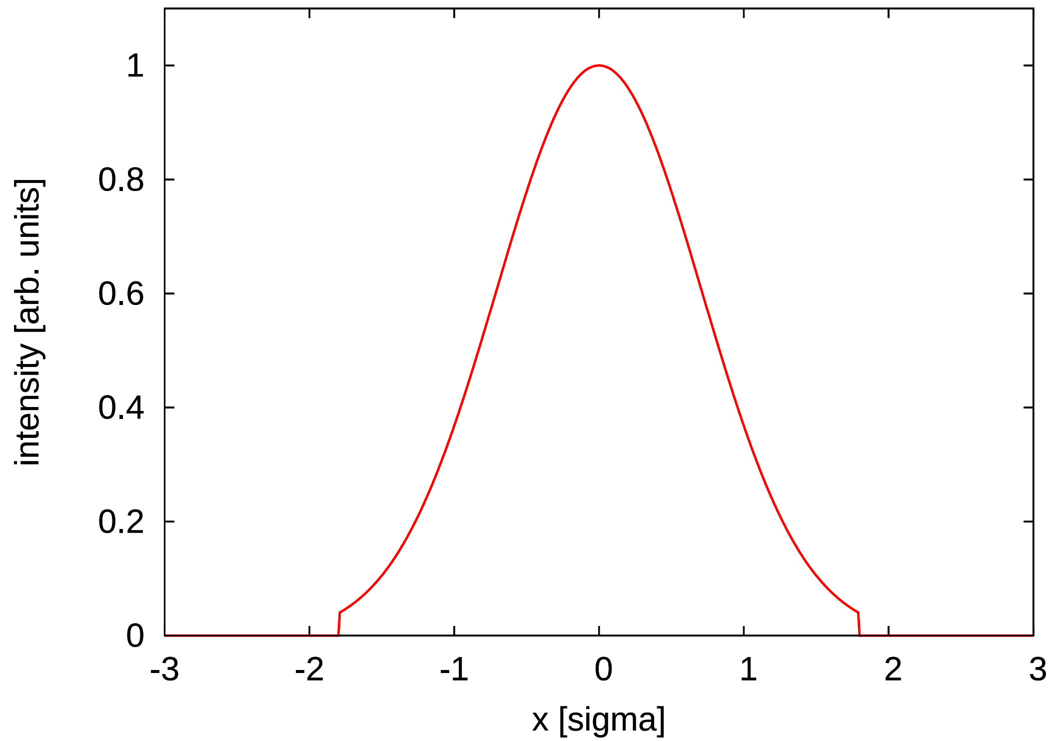
Requirements (cont.)

- Gaussian electron beam profile



Gaussian profile would be ideal, rectangular profile disastrous

Electron lens profile has a sharp cut-off at 2.8σ due to limited cathode size:



Sharp edges are generally dangerous, but intensity in the tails is very low

(Cut-off shown at 1.8σ for illustrative purposes)

Requirements (cont.)

- Electron lens solenoid straightness

Consider solenoid to be composed of many thin slices:

- Random, uncorrelated Gaussian misalignment of those slices ("spatial white noise") just broadens the rms width of the electron beam, while keeping the profile Gaussian

- In reality, long wavelengths will dominate, resulting in profile distortion. For very large misalignment amplitudes, a double hump structure appears.

Accelerator studies at RHIC

1. Betatron phase shifter

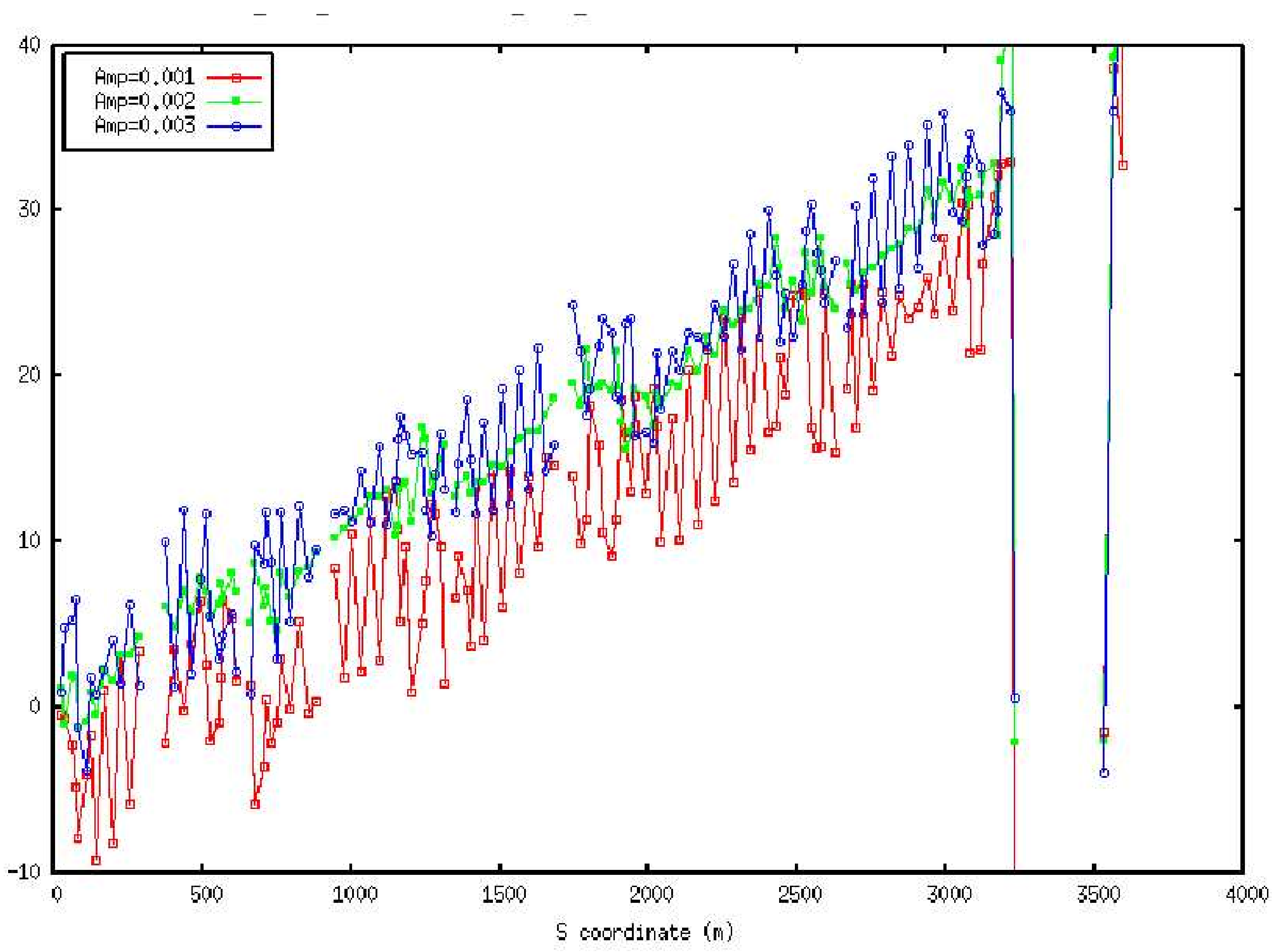
   - Two shunt power supplies will be added to main quads in arc IP8 - 10, to allow control of betatron phase advance

   - For successful operation, we have to be able to measure this phase advance with an accuracy of a few degrees

   - Changed RHIC tune by $\Delta Q \approx 0.1$ (or 30 degrees), which changes phase advance per arc by 5 degrees

   - Measured optics by AC dipole to verify the change in phase advance

Measured phase advance



2. Limit for lowering γ_t

- Integer tunes need to be modified to minimize optics distortions by betatron phase shifter
- Blue tunes: (27.69,29.68), Yellow: (29.69,30.68)
- Increasing the horizontal integer tune in Yellow will inevitably raise γ_t
- For good longitudinal matching, Yellow γ_t has to be lowered at injection, using γ_t quads and possibly lattice modifications
- APEX study to explore the limits

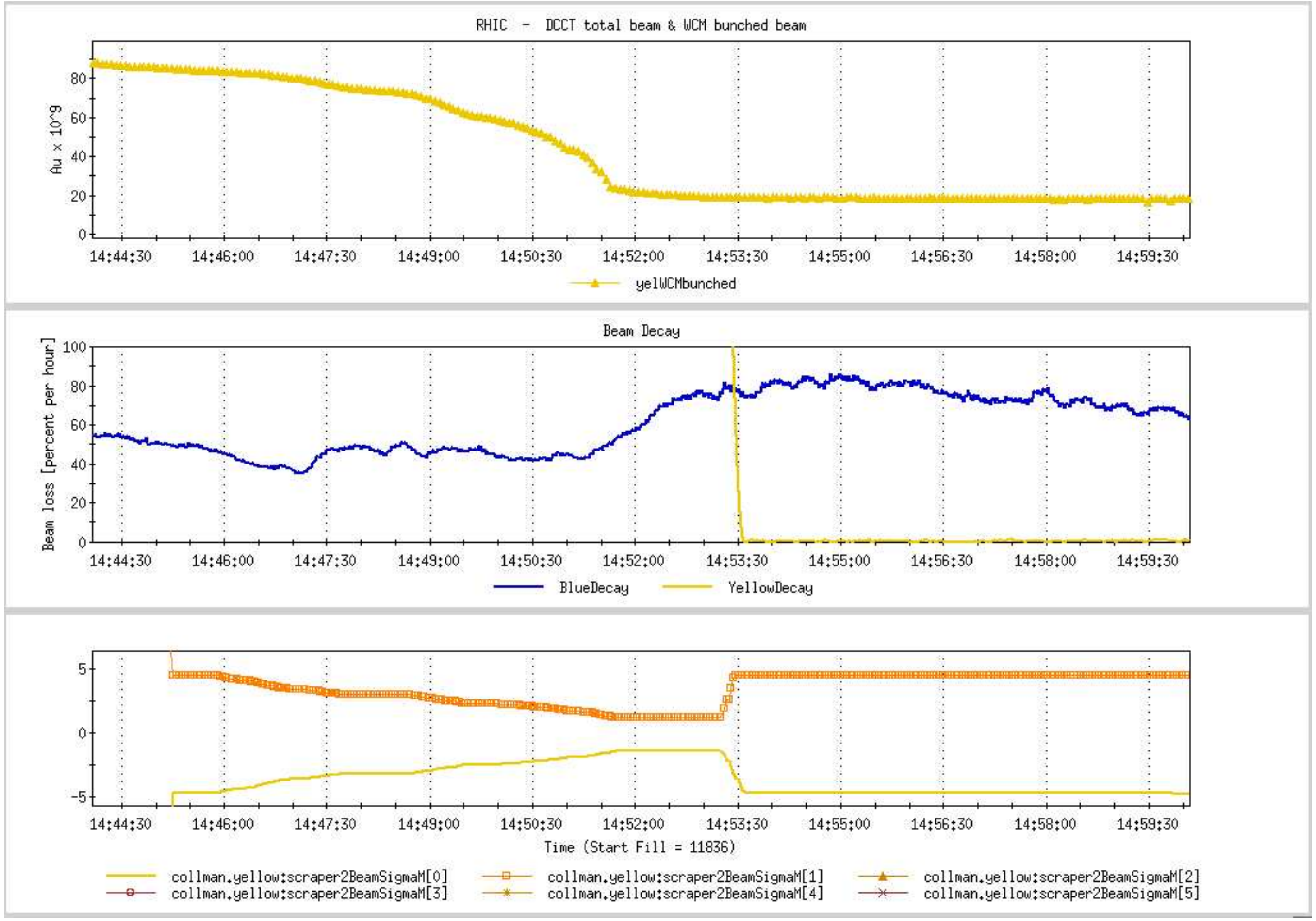
3. Effect of limited cathode size

- Established collisions at STAR with 111x111 at injection

- No luck finding collisions at PHENIX

- Re-injected, then started scraping in Yellow

Blue beam decay as function of Yellow collimator position



- Blue beam decay was still improving after injection when we started scraping in Yellow (lack of time)

- Blue beam decay stopped improving when Yellow collimators were inserted to 3σ

- Sharp increase in Blue beam decay with Yellow collimators at $\approx 1.7\sigma$, despite low Yellow bunch intensity

- Blue beam decay improved after retracting Yellow collimators, demonstrating that observed beam decay is not just due to blow-up via IBS

- Results were not reproducible during two subsequent attempts

4. E-lens straightness requirement

- In the thin-lens approximation, a non-straight electron lens beam is equivalent to a “smoke ring” in phase space

- Generate “smoke rings” by single kicks of different amplitude to bunches in the “Blue” beam

- Observe lifetime and emittance evolution of corresponding bunches in the “Yellow” ring